JOURNAL OF GEOSCIENCE EDUCATION **61**, 256–267 (2013)

C-MORE Science Kits as a Classroom Learning Tool

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ABSTRACT

To support teachers in enhancing ocean literacy, the Center for Microbial Oceanography: Research and Education (C-MORE) has developed a series of portable, hands-on science kits on selected topics in oceanography. This paper provides an overview of kit content, describes how the kits were developed, and evaluates their efficacy as a curriculum supplement in formal classroom environments by using two studies, a qualitative assessment of teacher experience and a quantitative assessment of student learning. The teacher surveys ($n = 45$) indicate the kits were used in a wide range of class types and grade levels, describe the kits as useful classroom tools that actively engaged students and resulted in meaningful learning, and strongly indicate that the teachers plan to continue to use the kits in the future. The student learning assessment ($n = 1{,}236$) employed a pretest, posttest 1, and posttest 2 methodology. The pretest and posttest 1 were given immediately before and after instruction, respectively; posttest 2 was given at least 2 weeks after instruction. Engaging with the science kits resulted in significant knowledge acquisition (pretest-posttest 1 mean differences of 0.21–0.41) and retention (pretest-posttest 2 mean differences of 0.18 to 0.39), with significance defined at the $\alpha = 0.05$ level. In the 2 weeks after kit instruction, all kits showed a slight, nonsignificant loss in knowledge (mean differences of -0.01 to -0.04). Together, the teacher and student evaluations indicate that the C-MORE kits are effective classroom tools that can serve as a model for hands-on curriculum supplements.

 [DOI: 10.5408/12-336.1]

Key words: assessment, evaluation, oceanography, science kits

INTRODUCTION

Ocean and Science, Technology, Engineering, and Mathematics Literacy

Virtually every aspect of modern life is influenced by science, technology, engineering and mathematics (STEM). Engaged citizens need to possess at least basic STEM literacy to make informed decisions about everything from personal health to public policy. Alarmingly, a third of U.S. middle school students failed to meet the basic achievement level in the most recent national science assessment (National Center for Education Statistics, 2012). These and similar reports highlight the need for vastly improved STEM education (e.g., National Research Council, 2010, 2011, 2012; National Academy of Engineering and National Research Council, 2012).

A key component of science literacy is ocean literacy. The ocean shapes Earth's features, makes our planet habitable, plays a pivotal role in weather and climate, supports great diversity of life, and can drive the creation of new technologies. The oceans are inextricably linked to the Earth, atmosphere, and life, and a basic knowledge of ocean science is critical to understanding global processes (Steel et al., 2005; National Geographic Society and National Oceanic and Atmospheric Administration, 2006; Strang et al., 2007). Unfortunately, marine science topics are not yet widely integrated into state and national standards, education frameworks, or teacher training programs. Therefore, while ocean sciences could easily be integrated into a range of science classes, they generally are not (Walker et al., 2000; Lambert, 2006; Clay et al., 2008; Schoedinger et al., 2010; Tran et al., 2010).

The development of the Next Generation Science Standards is underway to guide the future of science education (Achieve, Inc., 2012). *The Framework for K–12 Science Education* (Framework) has recommended that the Next Generation Science Standards be built around three major dimensions: (1) scientific and engineering practices, (2) crosscutting concepts that unify the study of science through common applications across fields, and (3) core ideas in the four disciplinary areas of physical sciences, life sciences, Earth and space sciences, and engineering–technology–applications (National Research Council, 2012). Ocean processes are among the crosscutting concepts cited in the Framework, and their inclusion is guided by the Ocean Literacy Principles (National Geographic Society and National Oceanic and Atmospheric Administration, 2006). Thus, the demand for flexible ocean science curricular materials that can be incorporated into a range of course types is likely to increase in the near future.

Science Kits and Hands-On Learning

To effectively learn science, students need to learn more than just facts and theories. Rather, they need to construct their understanding through an iterative, collaborative process that builds and reshapes prior knowledge (National Research Council, 2000, 2005, 2012). The most effective lessons tend to be hands-on and inquiry-based (Shymansky et al., 1990; Olson and Loucks-Horsley, 2000; Young and Lee, 2005), place-based (Gruenewald, 2003; Sobel, 2004), and/or relevant to current issues (Ballantyne et al., 2001). Students who participate in hands-on activities focused on scientific inquiry score more highly on national science tests (National Center for Education Statistics, 2012).

Received 8 June 2012; revised 21 March 2013; accepted 4 April 2013; published online 27 August 2013.

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Unfortunately, hands-on science education tends to be resource intensive, and many schools are experiencing financial shortfalls. One way that teachers can keep up to date with equipment and supplies is with science kits. Science kits contain all (or nearly all) of the equipment, supplies, and curricular materials needed to investigate a particular science topic. The most well known science kits are commercial—for example, Full Option Science System (Delta Education), Science and Technology for Children (Carolina Biological Supply Company), and Insights (by Kendall Hunt) (Lopez and Schultz, 2001). These kits, which can include 6 or 8 weeks of curriculum, have been shown to be effective at increasing student achievement and promoting positive attitudes toward science (Dickerson et al., 1996; Stohr-Hunt, 1996; Houston et al., 2003; Young and Lee, 2005). Unfortunately, they exceed the budget of many classrooms.

In recognition of the efficacy of commercial science kits, scientific and educational organizations are starting to develop their own kits as part of their outreach mission (e.g., Aquarium of the Pacific, 2012; Cascades East, 2012; Center for Microbial Oceanography: Research and Education, 2012; Missouri Botanical Garden, 2012; Ohio State University Extension, 2012). Unlike commercial kits, which are typically designed as stand-alone curriculum, these kits generally contain hands-on lessons and activities to supplement a teacher's existing curriculum. Little research, however, appears to have been done as to whether these "curriculum supplement" kits are effective educational tools.

This paper focuses on a collection of "curriculum supplement" kits created by the Center for Microbial Oceanography: Research and Education (C-MORE) on a range of topics in ocean science. First, we provide an overview of kit content and describe how the kits were developed, revised, and distributed through a system of lending libraries. We offer this information as a model for teachers or organizations interested in developing their own kits. We then evaluate the efficacy of the science kits as curriculum supplements in formal classroom environments through two studies, an assessment of teacher experience and an assessment of student learning. Our research questions are (1) What were the teachers' experiences in engaging with the kits? and (2) Does engagement with the science kits increase student knowledge and build ocean literacy?

C-MORE SCIENCE KITS

In 2009, C-MORE released a set of hands-on science kits on various topics in oceanography (Center for Microbial Oceanography: Research and Education, 2012). These "labs in a box" are designed to be curriculum supplements for a range of science courses and grade levels. Although the lessons in each kit make up a unit, many of the activities are discrete and can be rearranged to fit various curricular objectives and time constraints. No prior content knowledge or specialized training is required to use these kits, but teachers with limited background in ocean science are advised to review all resource materials provided prior to instruction.

Each kit contains hands-on supplies and paper and electronic materials, which include standards-based lesson plans, narrated and non-narrated versions of Microsoft PowerPoint presentations, resource materials (such as videos, data sets, and readings), teacher evaluation surveys, and supply checklists. All paper and electronic materials are available online (Center for Microbial Oceanography: Research and Education, 2012) and may be freely reproduced for educational, noncommercial purposes. To maintain the integrity of the assessment, answer keys to assessment materials are not provided online but may be obtained by contacting the C-MORE science kit manager (kits@soest.hawaii.edu).

Fourteen science kit lending libraries were established in the four states where C-MORE education efforts are concentrated: Hawaii, California, Massachusetts, and Oregon. Teachers (including informal science educators and homeschool parents) can borrow kits at no cost. First, they reserve the kit from a specified lending library location by using an online reservation system. Then, they are contacted by the lending librarian to arrange a pick-up time. As of December 2012, the kits have been used with at least 30,000 students and 325 unique educators from 235 organizations at grade levels ranging from kindergarten to college and at teacher development workshops.

Teachers outside of lending library service districts can access paper and electronic materials online to teach lessons by using supplies already on hand or that do not require hands-on materials. At least 58 teachers from 25 states and five foreign countries have done this, as evidenced by their request for answer keys to assessment materials. Alternately, teachers can purchase supplies, print the paper materials, and physically replicate part or all of a science kit. We are aware of 26 teachers from eight states who have done this. Teachers interested in replicating kits are welcome to contact the C-MORE kit manager for advice and assistance.

All C-MORE science kits are aligned with the state education standards and benchmarks for Hawaii (Hawaii Standards Database, 2005), California (California Department of Education, 2003), Massachusetts (Massachusetts Department of Education, 2006), and Oregon (Oregon Department of Education, 2009), as well as with the Ocean Literacy Principles (National Geographic Society and National Oceanic and Atmospheric Administration, 2006). Hawaii is the only one of these states with specific ocean-related standards for marine science courses.

Kit Content Descriptions

The five kits examined in this study are summarized below. Detailed lesson plans for each kit are provided as supplemental online documents.

(1) *Ocean Acidification*. The primary objective of this two-lesson kit is to introduce students to ocean acidification, the process by which the ocean is becoming increasingly acidic (Bruno et al., 2011). In brief, ocean acidification is caused by increasing carbon dioxide (CO_2) levels in the atmosphere. Some of this CO_2 dissolves in the ocean, where it combines with water to form carbonic acid, a weak acid. A more acidic ocean poses threats to marine

organisms. Lesson 1 (60 min) includes a simple, hands-on experiment demonstrating the impact of a weak acid on carbonate sand, a short presentation, and optional readings with worksheets. In lesson 2 (60 min), students conduct an experiment with Vernier probes to simulate the process of ocean acidification. They activate yeast, measure the CO_2 produced by yeast respiration, bubble CO_2 through water, and measure the resultant pH decrease that occurs as carbonic acid forms. After completing this kit, students should know about ocean acidification, the basic chemical relationship between CO_2 and water, the pH scale, and potential impacts of ocean acidification. (See Ocean Acidification Kit lessons, available online at http://dx.doi.org/10.5408/12-336s1.)

(2) *Ocean Conveyor Belt*. The objective of this four-lesson kit is to introduce students to fundamental oceanographic concepts such as water density, ocean circulation, nutrient cycling, and variations in the chemical, biological, and physical properties of seawater through hands-on and computer-based activities. In lesson 1 (70 min), students learn how water density changes with temperature and salinity by creating a stratified water tank. In lesson 2 (70 min), students learn how changes in water density drive global ocean currents by mapping and making a paper model of thermohaline circulation. Lesson 3 (70 min) introduces students to long-term oceanographic time-series data (Hawaii Ocean Time-series, 2013) to demonstrate how physical, chemical, and biological variables change with depth and time. Students graph and interpret seasonal changes in ocean temperature, phytoplankton, and nutrient abundances. Lesson 4 (70 min) integrates every principle in the kit about ocean circulation, biogeochemistry, and data interpretation. Students use online oceanographic databases to graph, analyze, and interpret data about nutrient concentrations in the Atlantic and Pacific Oceans. After completing lessons 1 and 2, students should know how temperature and salinity affect water density, that most of the ocean is stratified, that the ocean has a global circulation pattern called the ocean conveyor belt, and that ocean circulation influences climate. After completing lessons 3 and 4, students should know the relative age of ocean water, general nutrient relationships in the open ocean, and the basics about nutrient cycles. (See Ocean Conveyor Belt Kit lessons, available online at http://dx.doi.org/10.5408/12-336s2.)

(3) *Plankton*. The objective of this four-lesson kit is to introduce plankton and the crucial role they play in the marine food web. Most students are surprised to learn that there are microscopic organisms all around them when they swim in the ocean. In lesson 1 (40 min), students learn about phytoplankton (“plant-like” plankton) and their adaptations for survival. In lesson 2 (45 min), students design their own phytoplankton, based on observation and imagination. In lesson 3 (50 min), students collect a live zooplankton (“animal-like” plankton) sample with a net and investigate it with the digital microscope provided. In lesson 4 (60 min), students learn about environmental factors that affect phytoplankton growth and distribution, and run a computer simulation to model phytoplankton blooms. After completing lessons 1 through 3, students should have learned about phytoplankton and zooplankton, including their survival adaptations, their roles in the marine food web, and their influence on climate. After completing lesson 4, students should know about environmental factors that affect plankton growth. (See Plankton Kit lessons, available online at http://dx.doi.org/10.5408/12-336s3.)

(4) *Random Sampling*. There are millions of microbes in a single drop of sea water, but how do scientists count them? The objective of this kit is to introduce random sampling, a key concept used to study the natural environment (Bruno et al., 2010). In lesson 1 (50 min), students study the abundance and diversity of marine microbes. Differently colored beads represent different species of microbes, and the bag containing the beads represents the ocean. Working in groups, students randomly select a subset of beads from the “ocean” and compare the composition of their samples with that of the entire population. They learn that one does not need to count every individual to get a good representation of a population, provided that the sampling method is random. In lesson 2 (50 min), students are introduced to Microsoft Excel by inputting and graphing their lesson 1 data. In lesson 3 (50 min), students use chi-square statistics to assess how well their samples represent the total population. After completing lesson 1, students should know what a random sample is and how to randomly sample a population. After completing lesson 2, students should know how to make a simple Excel graph. After completing lesson 3, students should know how to use statistics to compare random samples to the population. (See Random Sampling Kit lessons, available online at http://dx.doi.org/10.5408/12-336s4.)

(5) *Marine Debris*. This three-lesson kit explores marine debris and its environmental impacts. In lesson 1 (60 min), students complete six hands-on activities to explore how marine debris can harm marine organisms, such as through entanglement and ingestion. In lesson 2 (80–90 min), students learn how surface ocean currents form and how currents can transport debris far from the source. They trace potential marine debris tracks by using the Ocean Surface Current Simulator, an online ocean surface current model (National Oceanic and Atmospheric Administration, 2013) to determine the geographic origin of the debris. In lesson 3 (60 min), students learn how some scientists study marine debris and engage in a discussion about what they can do to help with this important problem. After completing this kit, students would have learned the definition

of marine debris, its environmental impacts, that surface currents can transport debris across oceans, how surface currents form, and how they can help mitigate marine debris. (See Marine Debris Kit lessons, available online at http://dx.doi.org/10.5408/12-336s5.)

Kit Development

Each kit was developed through an iterative, collaborative process involving pilot tests and teacher feedback, during which the lessons were continually revised, as recommended by Briggs et al. (1991). First, researchers and educators brainstormed ideas and topics related to microbial oceanography of potential interest in the classroom. Then, we outlined possible ideas for standards-based lessons, incorporating technology and hands-on activities as much as possible. Much of the development stage involved researching and testing products to be used in the activities. Once we selected the best materials and experimental procedures, we wrote lesson plans to guide students—and teachers—through the experiments. All lessons and worksheets were field tested with a variety of student audiences in both informal and formal settings.

Throughout kit development, we solicited feedback from classroom teachers, both informally on a one-on-one basis as well as through organized teacher focus groups, where teachers reviewed and commented on draft materials. Although they held a range of opinions, several "big-picture" patterns emerged. We learned that teachers were looking for versatile curriculum supplements, not replacement curricula. They wanted hands-on lessons that related to "hot" topics that could be incorporated into their existing curriculum and aligned with state standards. They were virtually unanimous in *not* wanting a prescribed curriculum targeted at a specific grade or subject. They were especially interested in connecting with university-based research endeavors and accessing "real" data sets. When reviewing specific kits, teachers were especially helpful in gauging whether the lessons would be of interest to students and identifying conceptual leaps that needed bridging.

In response, we created science kits to explore "big ideas" that could be connected to a variety of science subjects and aligned them with state standards at a range of grade levels. For example, a fourth-grade teacher could use the plankton kit to ask students to "Explain how simple food chains and food webs can be traced back to plants," whereas a high school biology teacher might use the kit to discuss the important role of plankton to "Describe biogeochemical cycles within ecosystems" (Hawaii Standards Database, 2005).

Kit Production, Distribution, and Revision

Once the content materials for each topic area were finalized, we gathered the supplies and physically assembled 14 kits per topic area (one per lending library). To provide a sense of the scale of this effort, most of the kits contain supplies for five to seven student groups, so we purchased and/or created 70–98 individual items per group activity. Since most retailers do not stock large volumes of items, we had to scout out multiple supply sources and place numerous orders to accumulate sufficient supplies. Back-ordered supplies often held up kit assembly for weeks to months. Once all the kits were assembled, they were delivered or mailed to kit libraries. Lending librarians (science educators who volunteer to host the kits and support local teachers in kit usage) then had to be trained on kit use, either online, over the phone, or in person. The time to produce and release one set of 14 replicate kits took approximately 8–14 months. On the other hand, a teacher wishing to replicate a single kit could probably do so in a couple of weeks by using the supply lists in the kits or contacting the kit manager for assistance.

In the above paragraph, the word *finalize* is used loosely. Once the kits were released and teachers began to borrow the kits, we began to receive teacher feedback. Some teachers completed and returned the teacher survey included in each kit. Others contacted the kit manager or other C-MORE members with ideas, suggested edits, and requests for additional content. After at least a year of classroom use, the Plankton, Random Sampling, Ocean Acidification and Marine Debris kits were recalled, updated, and re-released. Updates included adding new student worksheets, revising student instructions for clarity, updating presentations with new information, and including pre- and post-surveys that were not included in the original release. For the Random Sampling kit, new material was added to better connect the activity to marine microbes. For the Marine Debris kit (in which problems were reported using the online ocean surface current model), new instructions were provided for an upgraded version of the computer model (National Oceanic and Atmospheric Administration, 2013). A recent addition to the kit collection, the Ocean Conveyor Belt, was released in 2010 and has yet to undergo major revision. Once the Next Generation Science Standards are adopted, all kits will be aligned to these new standards.

ASSESSMENT OF TEACHER EXPERIENCE

As of December 2012, a minimum of 325 unique educators from 235 organizations borrowed at least one science kit, reaching at least 30,000 students. Their experience with the science kits was assessed though an optional teacher evaluation included with each kit. The survey had two parts. First, teachers were asked to state their level of agreement with seven statements by using a Likert scale. Then, teachers were asked to respond to six open-ended questions and provide general comments. Teachers could either complete a pen-and-paper survey included with the kit or an online version (http://www.surveymonkey.com/s/CMORE-kit-evaluation). Hard copies of teachers' evaluations were input online for data compilation and analysis.

Forty-five teachers, or 14% of the 325 teachers who independently borrowed the kits from a C-MORE lending library, completed the evaluation. Although low return rates are fairly typical with optional evaluations, we note that they can skew results, either toward high or low satisfaction. The respondents were from Hawaii (33), California (6), Massachusetts (3), and Oregon (1); two respondents did not indicate a location. Of the 30,000 students using the kit, approximately 16% were in elementary school (K–5th grade), 33% in middle school (6–8th grade), 40% in high

TABLE I: Teacher feedback on using the science kits.

Question	Mean ± SD ($n = 45$)[1]
Online kit reservation was easy.	4.53 ± 0.80
Picking up this science kit was difficult.*	1.55 ± 1.08
This science kit was easy to use.	4.38 ± 0.87
The teacher guide was difficult to follow.*	1.49 ± 0.69
My students enjoyed using this science kit.	4.51 ± 0.75
I would not borrow this science kit in the future.*	1.48 ± 1.05
I will borrow other C-MORE science kits.	4.60 ± 0.80

[1]Teachers indicated agreement with statements by using the following Likert scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.
* = reversely worded questions; thus, low values indicate positive results.

school (9–12th grade), and 5% in college. The remaining 6% of kit usage occurred at teacher professional development workshops and adult education programs. Apart from grade level, no demographic information was collected on students of these teachers who independently borrowed the kits. However, detailed demographic information was recorded for the 1,236 students who participated in the student evaluation study described below (see "Assessment of Student Learning"), including ethnicity, grade level, academic level within their grade, and eligibility for free or reduced lunch.

Likert Scale Assessment

Teachers were asked to state their level of agreement with seven statements by using a Likert scale of 1 (strongly disagree) to 5 (strongly agree). Four statements were positively worded, so higher numbers correspond to more positive results. Three statements were reversely worded, as recommended by Nunnally (1978), so lower numbers correspond to more positive results. Teacher responses to Likert scale questions are detailed in Table I and summarized here; asterisks denote items that are reversely worded. In short, teachers found the kits easy to reserve (4.53), pick up (1.55*), and use (4.38). They found the teacher guides to be easy to follow (1.49*), and reported that their students enjoyed using the science kits (4.51). They indicated they would both borrow the given science kit again (1.48*) and would also borrow other science kits (4.60). These quantitative results indicate that the teachers who independently borrowed the kits had strongly positive experiences.

Open-Ended Questions

In addition to the Likert scale questions described above, teachers were also asked to respond to six open-ended questions to ascertain how they used the kits and to solicit their feedback and suggestions.

(1) *Are the time estimates given for each lesson reasonable? If not, please explain*. Approximately two-thirds (25) of the 38 teachers who responded to this question indicated that the timing provided in the lesson plans was reasonable; the remaining third (13) felt the time estimates were too short. Some teachers reported that they modified lessons to fit their time constraints, and several noted that the time required to complete the lessons varied with class type. For example, "In lab, I gave directions on a PowerPoint and had students follow along. This was much faster [Ocean Acidification]," and "My class is a SP[ecial]-ED[ucation] class with students with high-functioning autism, so I had to modify each lesson. I adapted each lesson (for SPED students), but [the timing] would work well in a general-ed[ucation] class [Plankton]."

(2) *How did you use this science kit?* The responses from 41 educators collectively indicated that the kits were being used in a variety of classes including biology, chemistry, Earth and space science, language arts, life science, marine biology, marine conservation, physical science, and statistics. In these classes, the kits were used "as a lead-in to sampling methods for rocky intertidal monitoring;" "to discuss chemical reactions, chemical properties, conservation of matter and the impact of humans on the environment," "to introduce classification, reproduction, currents, heredity, cycles of matter and energy, interdependence, inquiry, and unity and diversity," "to expand on the topic of scientific investigation," "to introduce ocean food webs, plankton, taxonomy and as an introduction to the microscope," "to introduce climate change," "to give students ideas of possible research projects they could develop," "to help students understand oceans' currents," "to reinforce simple random sampling and introduce some Excel features," "as part of a unit on ocean chemistry before ocean cycles," and "as an introduction to ocean circulation and geological oceanography."

(3) *Did you use the entire science kit? If you omitted any lessons or activities, please list which ones and explain why you skipped them*. Forty teachers responded to this question. Fewer than half (18, or 45%) used the entire kit. Seven respondents (18%) skipped one lesson, 5 (13%) skipped two or more lessons, and 10 (25%) modified the lessons. Reasons indicated for not using the entire kit included time constraints (e.g., "I ran into scheduling issues, otherwise I would have used the entire kit [Ocean Conveyor Belt]"), content considerations (e.g., "I skipped lesson 3 because I'm not introducing those topics

TABLE II: Numbers of students participating in the science kits evaluation.

Science Kit	Participating n^1	Listwise Valid n^2	ELL n (%)^3	IEP n (%)^4
Ocean Acidification	187	155	38 (20%)	18 (10%)
Ocean Conveyor Belt	327	270	10 (3%)	11 (3%)
Plankton	228	196	4 (2%)	11 (5%)
Random Sampling	220	201	4 (2%)	11 (5%)
Marine Debris	274	246	21 (8%)	12 (4%)
Total	1,236	1,068	77 (6%)	63 (6%)

[1]Participating n = number of students who participated in at least one survey assessment for a given science kit.
[2]Listwise valid n = number of students who completed all three survey assessments (one pretest and two posttests) for a given science kit.
[3]ELL = English language learners. ELL data were provided by teachers and not linked to specific survey data.
[4]IEP = Individualized Education Program students. IEP data were provided by teachers and not linked to specific survey data.

until second semester [Random Sampling],'' and ''I was using it as a survey and introduction and I didn't require the students to do everything in the kit [Marine Debris]''), and grade level (''I skipped [lessons] 3 and 4 due to age level [Ocean Conveyor Belt]'').

(4) *Were your students involved and interested in the science kit activities?* All 45 respondents to this question replied positively. Sample comments include: ''Yes, they even took pictures of their product during and at the end of the assignment [Ocean Conveyor Belt]'', ''Definitely, they were fully engaged. It is evident by their thoughtful questions and the attention they paid to completing the data sheet [Plankton]'', and ''Yes, they were eager to see if their predictions were accepted or rejected [Ocean Acidification].'' One teacher responded, ''I decided to scrap my regular introduction to the microscope lab and instead combined it with the zooplankton lesson [lesson 3] in which the students looked at our bay water . . . The water was filled with phytoplankton and zooplankton. To quote several students and give you the general idea of how it went, 'This was the best science class I've ever had!' rang throughout the room. The kids were so excited—I was being pulled in 11 directions at once to go see what they'd found swimming in the bay water with their microscopes as they were individually calling out, 'Mrs. —, come see this!' [Plankton].''

(5) *Please suggest two things that could be improved*. Thirty-seven respondents suggested both technical improvements and additional components that they would like to see included with specific kits. Suggestions for technical improvements included ''New boluses for dissection, as the ones in the kit have been dissected quite a bit. Also new/more samples of marine debris which organisms have attached/made homes on [Marine Debris],'' and ''I would increase the copies of all the laminated work to at least 10–12 of each. With class sizes increasing and individual educational plans for diverse populations, it's often better to have students work in the smallest groups possible for some activities [Plankton],'' and ''Being new to tech science equipment [Vernier], my students would have been able to accomplish the CO_2 and pH experiments more efficiently if the two experiments had come in separate Baggies [Ocean Acidification].'' Suggestions for additional components included ''I would have liked to have some actual prepared slides of some of the plankton [Plankton],'' and ''A bucket would have been useful to get seawater for diluting the sample [Plankton].''

(6) *Any other comments?* Responses from the 26 teachers answering this question included ''Marine Debris is an easy kit to connect with my students' daily lives,'' ''The Ocean Acidification kit was great, my kids loved doing a real scientist science lab,'' and ''The students were amazed at the world of plankton. Some of them have very little science background, and the lessons were designed so that they got as much out of them as the students who have more experience in science [Plankton].''

These qualitative responses, together with the quantitative Likert scale data (shown in Table I and summarized above), strongly indicate high satisfaction with the science kits among teachers who independently borrowed the kits and taught the lessons. Naturally, student learning is the ultimate arbiter of high-quality instructional materials, and this is assessed in the next section.

ASSESSMENT OF STUDENT LEARNING

From August 2010 to February 2011, we conducted an assessment to determine whether any significant gains in student learning occurred as a result of engagement with the science kits. The assessment was conducted in partnership with two external evaluators and eight classroom science teachers at six middle and high schools in Hawaii. The eight teacher participants responded to a request posted on the Hawaii Science Teachers Association email list. The students were in grades 7–12 and spanned a range of academic levels, including general lower, mixed, honors, and gifted and talented. A total of 1,236 students participated in the evaluation, with the number of students participating in each individual kit evaluation ranging from 187 to 327.

Table II summarizes the number of students who took part in each kit evaluation, including those who were English-language learners and Individualized Education

TABLE III: Knowledge acquisition: descriptive statistics and paired Student's *t*-tests of student scores on the pretest and posttest 1.

Science Kit	Pairwise Valid *n*	Pretest[1,2]	Posttest 1[1,2]	Difference[3]	Student's *t*-test	*p* Value
Ocean Acidification	167	0.48 ± 0.21	0.81 ± 0.18	0.33 ± 0.24	17.71	<0.001
Ocean Conveyor Belt	296	0.42 ± 0.22	0.64 ± 0.20	0.21 ± 0.24	15.24	<0.001
Plankton	207	0.45 ± 0.17	0.85 ± 0.16	0.40 ± 0.21	27.38	<0.001
Random Sampling	211	0.55 ± 0.23	0.77 ± 0.23	0.22 ± 0.25	12.77	<0.001
Marine Debris	253	0.60 ± 0.23	0.87 ± 0.18	0.27 ± 0.23	19.01	<0.001

[1]The pretest and posttest 1 were given to students immediately before and after science kit instruction, respectively.
[2]Values are means ± SD.
[3]Difference = posttest 1 minus pretest. Values are means ± SD.

Program students. The demographics of the participating students represent the diverse population of Hawaii, with 31% of the students Native Hawaiian or Pacific Islander, 29% Filipino, 20% Caucasian, 14% Asian, 3% African American, and 3% Hispanic. Almost half of the students (47%) participate in a free or reduced-price lunch program. Student ethnicity and economic status were determined from school demographic data (Accountability Resource Center Hawaii, 2012) and not tracked for comparisons between groups in this study.

This study was reviewed by the University of Hawaii's Committee on Human Studies and determined to be exempt from Department of Health and Human Services Regulations, 45 CFR, Part 46. Nevertheless, parents were notified by way of a letter sent home with the students that their child(ren)'s class would be participating in an educational study. Parents submitted a signed consent form granting permission for their child(ren) to participate in the study. Additionally, students signed consent forms acknowledging their participation. Students whose parents declined consent or who declined to participate in the study themselves still participated in all science kit activities and surveys, but their data were not included in the results.

Student knowledge was assessed by using part or all of the surveys included with each of the science kits. For three kits, our evaluation utilized the entire survey: Ocean Acidification (8 questions), Marine Debris (5 questions), and Random Sampling (5 questions). For two kits, our evaluation utilized only part of the survey, because these surveys are divided according to age group-appropriate lessons. As our goal was to assess the kits across a range of grade levels, we omitted upper-level surveys from our evaluation. For the Ocean Conveyor Belt kit, we only administered survey questions on lessons 1 and 2 (7 questions). For the Plankton kit, we only administered survey questions on lessons 1–3 (10 questions). The surveys contain a combination of multiple choice and true–false questions intended to assess the knowledge, comprehension, and application of topics presented in each kit. The survey used with the Plankton kit is included as an example (Appendix 1).

The surveys were administered at three stages: (1) immediately prior to science kit instruction (pretest), (2) immediately after science kit instruction (posttest 1), and (3) approximately 2 weeks after science kit instruction (posttest 2). At each stage, the identical survey was administered, and each completed survey was assigned a decimal grade corresponding to the percentage of questions answered correctly. A comparison of pretest and posttest 1 scores allows us to assess any knowledge gain that may have been *acquired* as a direct result of science kit instruction. A comparison of pretest and posttest 2 scores enables us to measure whether knowledge was *retained* 2 weeks after science kit instruction. A comparison of posttest 1 and posttest 2 scores allows us to assess whether any knowledge gain was *lost* in the time after the kit was completed.

For each comparison, mean values were computed, and statistical significance was determined by using a paired Student's *t*-test for each science kit. Each comparison only included data from students who completed both respective survey instruments (pairwise valid *n*). Evaluating whether these mean differences are significant involves performing multiple statistical tests simultaneously, which requires a readjustment in the critical *p* value to avoid false-positive errors. The Bonferroni correction is the simplest, most conservative approach to readjust the critical *p* value: $p = \alpha/n$, where α is the desired significance level (0.05), and n is the number of tests performed (15) (Shaffer, 1995; Weisstein, 2011). Solving for *p* yields a critical *p* value of 0.003. Thus, for each comparison, $p < 0.003$ indicates statistical significance.

Knowledge Acquisition (Pretest Versus Posttest 1)

To evaluate knowledge acquisition for each kit, we compared student scores of the surveys given immediately before (pretest) and after (posttest 1) science kit instruction. Table III summarizes the descriptive statistics and *t*-test results for knowledge acquisition. For each kit, pairwise valid *n* ranged from 167 to 296. Mean values of pretest scores for each kit ranged from 0.42 to 0.60. Mean values of posttest 1 scores for each kit ranged from 0.64 to 0.87. Each kit showed a positive gain in knowledge, ranging from 0.21 to 0.40. All *p* values were <0.003, which indicates that all gains are statistically significant at the Bonferroni-adjusted critical significance level.

Knowledge Retention (Pretest Versus Posttest 2)

A comparison of pretest and posttest 2 scores enables us to measure whether the newly acquired knowledge was retained 2 weeks after science kit instruction. Table IV summarizes the descriptive statistics and *t*-test results for knowledge retention. For each kit, pairwise valid *n* ranged from 166 to 294. Mean values of pretest scores ranged from 0.43 to 0.60; these are similar but not identical to the pretest values shown in Table III due to slight differences in

TABLE IV: Knowledge retention: descriptive statistics and paired Student's *t*-tests of student scores on the pretest and posttest 2.

Science Kit	Pairwise Valid n	Pretest[1,2]	Posttest 2[1,2]	Difference[3]	Student's t-test	p Value
Ocean Acidification	166	0.48 ± 0.20	0.80 ± 0.22	0.32 ± 0.22	18.24	<0.001
Ocean Conveyor Belt	294	0.43 ± 0.22	0.60 ± 0.21	0.17 ± 0.23	12.71	<0.001
Plankton	206	0.45 ± 0.17	0.84 ± 0.17	0.39 ± 0.22	25.20	<0.001
Random Sampling	207	0.55 ± 0.23	0.73 ± 0.24	0.18 ± 0.25	10.46	<0.001
Marine Debris	257	0.60 ± 0.23	0.84 ± 0.19	0.24 ± 0.23	16.82	<0.001

[1]The pretest and posttest 2 were given to students immediately before and 2 weeks after science kit instruction, respectively.
[2]Values are means ± SD.
[3]Difference = posttest 2 minus pretest. Values are means ± SD.

pairwise valid n. Mean values of posttest 2 scores for each kit ranged from 0.60 to 0.84. Each kit showed a positive knowledge gain, ranging from 0.18 to 0.39. All p values were <0.003, again indicating statistical significance. This analysis shows that even 2 weeks after kit instruction, significant knowledge was retained since the pretest.

Knowledge Loss (Posttest 1 Versus Posttest 2)

To evaluate the size and significance of any knowledge loss in the 2-week period after posttest 1, a second posttest was given, and the results of the two posttests were compared. Table V summarizes the descriptive statistics and t-test results for knowledge loss. Posttest 1 means ranged from 0.64 to 0.87, and posttest 2 means ranged from 0.60 to 0.84. All kits showed slight loss of knowledge (mean differences of −0.01 to −0.04); however, none of these differences were statistically significant at the Bonferroni-adjusted critical value of 0.003 (All p values exceeded 0.007).

DISCUSSION

Assessment of Teacher Experiences

The C-MORE science kits were borrowed by teachers at all grade levels, from kindergarten through undergraduate. Forty-five teachers who used the kits with grades 2–12, as well as college classes, responded to the optional kit evaluation. Respondents agreed that the kits were easy to reserve and borrow from lending libraries, that the instructions were easy to follow, and that kits were easy to use. They indicated that they would continue to use the kits in the future.

The teachers successfully utilized the kits as a curriculum supplement in nine different subject areas, especially in biology, chemistry, and marine science. Presumably, teachers referred back to the kits as they continued their units, and one teacher indicated that students continued to discuss the kits long after the activities ended. A formal longitudinal survey could address whether teachers and students continued to refer to the kits, but this was beyond the scope of our evaluation.

Assessment of Student Learning

Survey results for all kits showed significant increases in knowledge from the pretest to posttest 1. Students retained this knowledge from the pretest to posttest 2, which was administered at least 2 weeks after the end of kit instruction. Student survey scores showed a slight, nonsignificant loss of knowledge between posttest 1 and posttest 2. Based on these results, we can conclude that using the C-MORE science kits resulted in the following knowledge gains on topics directly related to the Ocean Literacy Principles. In the Ocean Acidification kit, students learned how increasing CO_2 in the ocean can change ocean chemistry. In the Ocean Conveyor Belt kit, students learned about water density and global ocean circulation. In the Plankton kit, students learned about plankton and the important role they play in marine food webs. In the Random Sampling kit, students learned how a random sample could be used to study marine microbes. In the Marine Debris kit, students learned about the environmental impacts of marine debris and how the debris is transported.

Overall, the mean student scores on both posttests were approximately 80% or greater for the Ocean Acidification, Plankton, and Marine Debris kits; greater than 70% for Random Sampling; and at least 60% for Ocean Conveyor Belt. Interestingly, the three kits with the highest student posttest scores have each undergone major revisions and incorporated the most teacher feedback. The Random

TABLE V: Knowledge loss: descriptive statistics and paired Student's *t*-tests of student scores on the posttest 1 and posttest 2.

Science Kit	Pairwise Valid n	Posttest 1[1,2]	Posttest 2[1,2]	Difference[3]	Student's t-test	p Value
Ocean Acidification	158	0.81 ± 0.18	0.79 ± 0.23	−0.02 ± 0.21	−1.15	0.251
Ocean Conveyor Belt	270	0.64 ± 0.20	0.60 ± 0.20	−0.03 ± 0.21	−2.67	0.008
Plankton	204	0.85 ± 0.15	0.84 ± 0.17	−0.01 ± 0.17	−1.05	0.293
Random Sampling	202	0.77 ± 0.23	0.73 ± 0.24	−0.04 ± 0.19	−2.68	0.008
Marine Debris	252	0.87 ± 0.18	0.84 ± 0.20	−0.02 ± 0.16	−2.31	0.022

[1]Posttest 1 and posttest 2 were given to students immediately after and 2 weeks after science kit instruction, respectively.
[2]Values are means ± SD.
[3]Difference = posttest 2 minus posttest 1. Values are means ± SD.

Sampling kit (posttest values of >70%) has undergone intermediate-level revisions, with slightly less teacher feedback received. The Ocean Conveyor Belt kit, which had the lowest posttest scores, has yet to undergo a major revision to incorporate teacher feedback. This appears to indicate that incorporating input from active classroom teachers results in more effective classroom tools and thereby increases student learning.

One of the limitations of our study is that we did not formally survey teachers to discover what topics they covered prior to using the kits or between posttest 1 and posttest 2. This would have helped us determine if student gains were solely the result of kit use or due to a combination of kit use and the teacher's "normal" curriculum. Given the significant increase in student scores between the pretest and both posttests and the slight but nonsignificant loss in knowledge between posttests, it appears that the knowledge gains are the result of participating in the science kit exercise.

Broader Impacts of Kit Use

Teacher comments from unsolicited emails and informal interviews indicate that kit use promoted meaningful learning that extended beyond knowledge acquisition and retention evaluated in the surveys. For example, after using the Ocean Acidification kit, high school students contacted scientists and policy makers to take action to help alleviate ocean acidification. A teacher using the Plankton kit told us, "One girl was so excited about microbes and looking at things through a microscope that she brought in some slides today from home. I love it when I can get students genuinely excited about something—enough so that they want to take their own time to investigate more." Another teacher using this kit shared, "A couple of students and I . . . Our idea is to study and identify the different types of plankton around the island of O'ahu." Feedback on the Ocean Conveyor Belt kit included "When I had [the students] list the things we've covered this year, Ocean Density came up without any prompting from me!!! Wow!! That's amazing! To think they've remembered that from so many months ago ... when they don't even remember what I talked about yesterday."

The Marine Debris kit appears to have particularly inspired students. After engaging with the kit, students participated in beach clean-ups, organized clean-ups around their school to stop the trash from reaching the ocean, encouraged their families to change purchasing habits to reduce the use of plastic, discouraged their peers from littering, and educated others about the environmental impacts of marine debris. Thus, participating in the kits not only increased content knowledge, but also inspired students to apply their knowledge outside the classroom.

SUMMARY

C-MORE science kits (hands-on curriculum supplements on various topics in oceanography) were evaluated in formal classroom environments in two ways: qualitative assessment of teacher experience and quantitative assessment of student learning. The teacher surveys ($n = 45$) indicate the kits are versatile (e.g., used in a wide range of class types and grade levels), are easy for teachers to borrow and use, actively engage students, and result in meaningful learning (e.g., students applying the knowledge to situations outside of the classroom). The student evaluation ($n = 1{,}236$), which employed a pretest, posttest 1, and posttest 2 survey methodology, indicates significant knowledge acquisition (pretest-posttest 1 mean differences of 0.21–0.40), significant knowledge retention (pretest-posttest 2 mean differences of 0.17–0.39), and a slight but nonsignificant loss in knowledge in the 2 weeks after instruction (posttest 1-posttest 2 mean differences of −0.01 to −0.04). Together, the teacher and student evaluations indicate that the C-MORE science kits are effective classroom tools that can serve as a model for hands-on curriculum supplements.

Acknowledgments

Numerous scientists, classroom teachers, informal science educators, and evaluators contributed to the development, revision, and evaluation of these science kits, particularly Kate Achilles, Bill Budenholzer, Debb Clevenger, Scott Doney, Leslie Kang, Scott La Chance, Kendra Martyn, Joan Matsuzaki, Laurie Morihara, Noelani Puniwai, Sarah Sherman, Dave Strang, Kimberley Thomas, Sara Thomas, Kimberly Tice, Sarah Waterman, and Erin Yagi. The lessons were field tested in dozens of schools and other venues, and we are grateful to everyone who participated and provided feedback. We are grateful to the editorial and peer reviewers whose suggestions resulted in a greatly improved manuscript. This project was funded by C-MORE (National Science Foundation EF-0424599) and the Hawaii Innovation Initiative.

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APPENDIX 1

PLANKTON SURVEY – LESSONS 1, 2, and 3
VERSION 2

Name:______________________________

Check one:
_______ Pre-survey
_______ Post-survey

Period: ______________________________

Directions:
This survey is both a pre- and post- survey. Put a check mark at the top of this paper next to the survey you are doing (pre- or post- survey). Please answer each question to the best of your ability. Circle the most correct answer.

1. What is the general term for animals that drift in the ocean?
   a. copepods
   b. holoplankton
   c. meroplankton
   d. zooplankton

2. These organisms photosynthesize and form the base of the ocean food web.
   a. crustaceans
   b. copepods
   c. phytoplankton
   d. zooplankton

3. Which of the following adaptations would not help phytoplankton float in the photic (light) zone?
   a. chlorophyll
   b. spines
   c. forming chains of cells
   d. flagella (hair-like tails)

4. Animals in the ocean could survive without plankton.
   a. True
   b. False

5. Which of the following shows energy flow through a simple ocean food chain?
   a. sun → diatoms → copepods → fish → whales
   b. sun → copepods → fish →diatoms → whales
   c. sun → fish → diatoms → copepods → whales
   d. diatoms → sun → fish → whales → copepods

6. Which of the following reduces greenhouse gas in the atmosphere?
   a. meroplankton
   b. copepods
   c. zooplankton
   d. diatoms

7. Which best defines the difference between holoplankton and meroplankton?
    a. Meroplankton photosynthesize. Holoplankton don't.
    b. Meroplankton are smaller and more abundant than holoplankton.
    c. Meroplankton are only plankton when they are young. Holoplankton are always plankton.
    d. Meroplankton stay near the lit ocean surface. Holoplankton are found throughout the ocean.

8. Which best describes why plankton are important to people?
    a. Plankton create much of the oxygen that humans breathe.
    b. Plankton support all the marine organisms that humans eat.
    c. Plankton are a potential source of medicine.
    d. all of the above

9. Human activities can increase CO_2 in the ocean, and this increased CO_2 can be harmful to marine organisms. Which of the following may help decrease CO_2 in the ocean?
    a. phytoplankton blooms
    b. zooplankton migration
    c. meroplankton
    d. holoplankton

10. If you were a scientist who studied phytoplankton, which tool would <u>not</u> help you study these organisms?
    a. a satellite photo
    b. a stethoscope
    c. a plankton net
    d. a microscope

11. If copepods disappeared, which would most likely increase?
    a. fish
    b. diatoms
    c. humpback whales
    d. cnidarians